Replacement Page 1, Lines 1 to 3

~~Description~~

Methods for Acquiring Shapes from HEp-2 Cell Sections and the Case-Based Recognition of HEp-2 Cells

BACKGROUND OF THE INVENTION

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SUMMARY OF THE INVENTION

The present invention ~~specified in claims 1, 4 and 17 to 19~~ is based on the object of obtaining abstract shape models from images representing HEp-2 cell sections for a case database as well as of being able to determine objects automatically from digital images with objects by comparison with cases.

This object is solved by means of the features listed in the independent claims ~~1, 4 and 17-19~~.

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~~Advantageous embodiments of the invention are set forth in claims 2, 3, and 5 to 16.~~

Advantageously, ~~according to the embodiment of claim 2,~~ the distance values and/or similarity values provide a distance matrix or similarity matrix.

~~In accordance with the embodiment of claim 3, the~~ The distance values or the similarity values are advantageously hierarchically represented by means of single linkage method and a dendogram.

According to ~~the~~ another embodiment ~~of claim 5~~, at least two cases are compared with one another, respectively, wherein the cases are oriented toward one another and scaling and/or rotation is carried out. Advantageously, at the same time the similarity is calculated, wherein similarity parameters are determined either as distance values or similarity values between the cases, respectively, until either a minimum of the distance values or a maximum of the similarity values is present.

Advantageously, ~~according to the embodiment of claim 6,~~ the dendogram on the similarity scale is intersected at least once according to either determined, and thus automatic, or user-specific thresholds so that groups will be generated. The individual shapes are correlated with the groups and within the groups a prototype is selected, wherein the prototype is either an averaged shape that is averaged based on the individual shapes of the group or the median of the group of individual shapes. In this way, a visual control of individual groups and/or the individual objects is provided. The averaged shape or the median of the group is represented on the data viewing device and its contour points are saved as a data set in the computer.

In accordance with ~~the~~ another embodiment ~~of claim 7~~, advantageously a reduction of the data obtained by tracing the edges and thus of the points as the visible outer and/or inner

contours is done by interrelation with a polynomial.

The cases correlated with the scanned edges are advantageously transformed ~~in accordance with the embodiment of claim 8~~ such that the center point of a case corresponds to the coordinate origin 0, 0. The cases are aligned within a coordinate system so that a comparison with regard to their similarities relative to one another is possible easily.

The calculation of the similarities is based on the determination of similarity parameters. In this connection, at least one case and one object are compared with one another wherein they are oriented toward one another and scaling and/or rotation is carried out. At the same time, the similarity is calculated wherein~~, according to the embodiment of claim 9,~~ similarity parameters are determined either as distance values or similarity values between the case and the object, respectively, until either a minimum of the distance values or a maximum of the similarity values is present.

Advantageously, ~~in accordance with the embodiment of claim 10,~~ a gradient image is generated by means of edge detection of the objects of the digital image wherein gradients are assigned to large changes of the grayscale in vertical direction as well as in horizontal direction while no gradients are assigned to homogenous surfaces. The homogenous surfaces are black. The result is an image with white edges of the object while the surfaces enclosed by the edges of the objects and the surfaces adjoining the edges of the object are black. The data set of the digital image is thus significantly reduced in comparison to a grayscale image of the digital image. At the same time, the computation expenditure is reduced for comparing each object with the selected case by the calculation of the similarities with the determination of the similarity parameters. Moreover, stacked and partially overlapping objects in the digital image can be more easily determined by comparison with a selected case.

According to ~~the~~ another embodiment~~ of claim 11~~, a gradient image is generated based on the case image as well as the object image, respectively, and the gradient images each

are transformed into an image sequence as a pyramid with image planes, wherein successively the directional vectors in the image planes of the case image and the object image, respectively, are compared with one another by forming the product. The principle of pyramids reduces the computational expenditure significantly. The respective subsequent image planes of the pyramids are representations of a raster that is twice as coarse. For this purpose, only every other point of a line and only every other line are picked and combined to a new image as an image plane. The employed tracing theorem ensures at the same time that the original finer raster can be exactly reconstructed based on the coarser raster. When comparing the cases and the object, one starts advantageously with the coarsest raster of the uppermost image planes. Depending on the result of the comparison of the similarity, successively image planes are compared with one another with the finer raster, respectively. The comparison can be interrupted at any time so that the computational expenditure for the comparison can be reduced significantly.

According to ~~the~~ a further embodiment ~~of claim 12~~, a dendogram represents an advantageous differentiation means of individual cases wherein groups of individual cases are hierarchically ordered. In this connection, the case image is a prototype of a group of individual cases wherein the groups are sets of similar individual cases with certain distance values or similarity values. The most similar case determines the branch of the dendogram with similar cases for determination of the object. The prototype is either an averaged shape averaged from the individual shapes of the group or the median of the group of individual shapes. The median is the case from which all other cases have the smallest spacing. The median represents thus a natural HEp-2 cell while the averaged shape is an artificial HEp-2 cell. However, the case image can also be an individual image of an object.

By means of determining the directional vector between either two points or neighboring points of the edges either in the case image or in the object image ~~in accordance with the embodiment of claim 13~~, the direction of the edge as a local orientation is determined so that the components of the course of direction of the local orientation and of the expression, measured e.g. based on the height or the slant of the edge, are incorporated

into description of the edge. In this way, advantageously also the surroundings of the existing complex structure of the image information can be incorporated into the calculation of the similarities. In the calculation of similarities, the similarity parameters are thus determined as directional vectors as well as distance values or similarity values between the case image and the object image. Additional information of the digital image is thus advantageously also considered when comparing by means of calculation of similarity.

According to ~~the~~ a further embodiment ~~of claim 14~~, either the prototypes or the cases are ordered by means of an index in accordance with the similarity relations in the case database. The index characterizes an index register with the prototypes and/or the cases individually or in groups wherein from a set of prototypes and/or cases the most similar prototype or case in comparison to the object in the image can be found quickly.

The calculation of similarity is realized advantageously according to the following formula ~~of the embodiment of claim 15~~.

$$D(P,O) = \sum_{i=1}^{N} \left| \frac{(p_i - \mu_p)}{\delta_p} - R(\Theta) \frac{(o_i - \mu_o)}{\delta_o} \right|^2$$

wherein

P and O - the objects

Θ - the rotation matrix,

μ_p and μ_o - the center points of the objects P and O, and

δ_p and δ_o - the sums of the squared spacings of each point from the center points.

~~The~~ Another embodiment ~~according to claim 16~~ advantageously provides that a non-identical object can be determined as a case manually and assigned to the dendogram with the determined cases. In this way, the case database can be expanded continuously.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be explained in more detail in the following with the aid of the illustrations.

It is shown in:

Fig. 1 an illustration with labeled and approximated contours of sectioned HEp-2 cells;

Fig. 2 the illustration with numbered representations of the sectioned HEp-2 cells of Fig. 1; and

Fig. 3 a dendogram of these HEp-2 cells.

DESCRIPTION OF PREFERRED EMBODIMENTS